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Review:

Video-assisted thoracic surgery—the past, present status and the future

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Abstract: Video-assisted thoracic surgery (VATS) has developed very rapidly in these two decades, and has replaced conventional open thoracotomy as a standard procedure for some simple thoracic operations as well as an option or a complementary procedure for some other more complex operations. In this paper we will review its development history, the present status and the future perspectives.

Key words: Video-assisted thoracic surgery (VATS), Pneumothorax, Empyema, Lung cancer, Esophagus, Mediastinum
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VATS, THE PAST

Historical perspective

The application of thoracoscopy can be traced back to nearly one hundred years ago, when Dr. Jacobaeus (1910) first reported his experiences in the diagnosis and treatment of pleural effusions by thoracoscope in 1909. Most patients who needed to undergo thoracoscopy at that time suffered from pulmonary tuberculosis (TB) ("the era of enthusiasm") (Cutler, 1933), and was rarely performed after the development of chemotherapy for patients with TB after the 1950s ("the era of neglect") (Viskum and Enk, 1981). The development of fibro-optic light transmission, the illumination and the image processing techniques, as well as the refinement of related instruments made video-assisted thoracoscopy more easily and broadly applied after the 1990s ("the era of revolutions and rapid development") (Mack *et al.*, 1992; Miller *et al.*, 1992; Mulder, 1993). And now video-assisted thoracic surgery (VATS) has become a basic and important technique for a thoracic surgeon.

Traditional thoracoscope

The structure of traditional thoracoscope is similar to other traditional endoscope. It is a hollow tube with a small light bulb over the tip of the scope. It belonged to the type of direct line of sight vision with distally lighted tubes. The traditional thoracoscope has the following limitations: first, the magnitude of the image is limited; second, only the operator can see the operation field clearly; and last, the functions of the assisted instrument are not so good (Jacobaeurs, 1923).

Video-assisted thoracic surgery (VATS)

The introduction of video-assisted imaging system amplifies the function of thoracoscopy. It cannot only magnify the image with the aid of better instruments, but also share the images with all people performing this procedure (Kaiser and Daniel, 1993). The minimal requirements of VATS include a zero- and/or 30 degree rigid telescope(s), a light source and cable, a camera and an image processor. The optional devices include a slave monitor, a semi-flexible telescope and a video-recorder (Krasna and Mack, 1994). The choice of the telescope diameter can range from 3 mm to 10 mm, depending the type of procedure. The 30 degree angled viewing scope can help us check the pleural cavity with broader visual field

(Landreneau *et al*., 1992b). The choice of light source and cable should accord with the output power, the source of light and the light transmission medium. The recommended light source and the output power for the video-assisted thoracic surgery are inert gas (eg. Xenon) mediated "cold light" at 300 W, higher than that used in other endoscopes (Rivas *et al*., 2002). The reason why VATS needs higher light output power is that the blood in the operation field will absorb up to 50% of the light (Berber and Siperstein, 2001). Regarding the light transmission, thinner light fibers lead to better light transmission. The light transmission media can be classified as glass or quartz. The best light transmission media is the quartz. Better light transmission can also reduce the thermal injury to the light cable. However, quartz is expansive and fragile (Schwaitzberg, 2001). The most commonly used camera in the VATS is the CCD (charged-coupled device) type, which can convert the light signals to digital ones (Berber and Siperstein, 2001). The number of prisms used in the camera can be one (one chip) or three (three chips), and the latter is usually selected for VATS because it can correct the chromographic phase differences (especially from the red light) (Berber and Siperstein, 2001).

VATS, THE PRESENT STATUS

In pneumothorax

1. Spontaneous pneumothorax

The crucial role of video-assisted thoracic surgery (VATS) in the treatment of spontaneous pneumothorax is well acknowledged today. Spontaneous pneumothorax (SP) can be treated by various methods, ranging from observation or chest tube drainage to bullectomy or pleurectomy (Jacco *et al*., 2000). VATS has been applied to treat SP since the 1990s, and had gradually become the standard treatment for SP (Cardillo *et al*., 2000). The indication of VATS in SP is changing, and not limited to patients with recurrent or primary SP (Hatz *et al*., 2000). The advantage of VATS is that it permits a minimally invasive, safe and effective procedure not only to treat the SP episodes but also to prevent recurrence (Horio *et al*., 2002). Spontaneous pneumothorax can be classified as of either the primary or secondary type. Primary spontaneous pneumothorax (PSP) is defined as a pneumothorax without underlying lung disease, and mostly affects young and thin males. It is usually caused by ruptured pleural blebs (Abdala *et al*., 2001). Secondary spontaneous pneumothorax (SSP) usually occurs in aged people where it is combined with other pulmonary diseases such as chronic obstructive pulmonary disease (COPD) or tuberculosis (Luh *et al*., 1996).

Although simple aspiration or chest tube drainage are still commonly applied for treatment of first episode SP, these procedures have major disadvantages such as lower success rate and higher recurrence rate (Andrivet *et al*., 1995). Schoenenberger *et al*.(1991) showed that 18% of patients with PSP and 40% with SSP treated by chest tube drainage had persistent air leakage, and that 25% to 50% of them suffered from recurrence during the follow-up period.

The introduction of VATS has led to other choices for SP management. At present, VATS has gradually become the preferred procedure for most PSP and some SSP because of the much better treatment effects and lower recurrence rate when compared with tube drainage or aspiration, as well as its minimal invasiveness compared with open thoracotomy (Hatz *et al*., 2000; Loubani and Lynch, 2000). Therefore, VATS for SP will not only reduce morbidity but also in the long run reduce costs (Liu *et al*., 1999; Hatz *et al*., 2000; Luh *et al*., 1996; Casadio *et al*., 2002).

There are many VATS procedures options for treating SP (Luh *et al*., 2004; Loubani and Lynch, 2000; Casadio *et al*., 2002; Sugamura *et al*., 2002; Horio *et al*., 2002). The major components of surgical intervention in SP include resection or ligation of blebs or bullae and obliteration of the pleural space. The use of the self-made endoscopic loop for ligation of parenchymal blebs or bulla in patients with SP has been proved safe and effective (Liu *et al*., 1997a). Most authors recommend blebectomy combined with some type of procedure to obliterate the pleural space which can be accomplished by parietal pleurectomy, talc powder spray, chemical or mechanical pleurodesis. Mechanical abrasion with the use of gauze packed instrument has proved to be effective in preventing pneumothorax recurrence. Loubani and Lynch (2000) and our previous study (Luh *et al*., 1996) recommended the use of additional tetracycline pleurodesis. However, Horio *et al*.(2002) found that additional pleurodesis by electrocauterizing the surface of parietal pleura in a patchy fashion can worsen postoperative chest pain or pulmonary function. We prefer to use mechanical abrasion only or combined with tetracycline intrapleural injection as the pleural obliteration procedure for SP.

2. Special type of spontaneous pneumothorax

Catamenial pneumothorax is a rare occurrence of spontaneous, recurring pneumothorax in women of menstrual age and has been associated with thoracic endometriosis. Three women had recurrent, menses associated with right sided spontaneous pneumothorax were observed by thoracoscope to have small perforations in the tendinous part of the right diaphragm with adjacent endometrial implantations. They were successfully treated by plication of this area (Korom *et al*., 2004) or wedge resection of lung parenchyma (Hsieh *et al*., 2000).

3. Traumatic pneumothorax

VATS for specific indications in trauma is associated with improved outcomes and decreased length of stay, as well as better diagnostic benefits.

The indication of VATS included: (1) management of retained hemothorax; (2) management of persistent pneumothorax; (3) evaluation of the diaphragm in penetrating thoracoabdominal injuries and management; (4) management of infected pleural space and collections; (5) diagnosis and management of on-going bleeding in hemodynamically stable patients (Korom *et al*., 2004).

In pleural effusion/empyema

1. Parapneumonic effusions or empyema

Parapneumonic effusion is defined as an accumulation of pleural fluid associated with an ipsilateral pulmonary infection. There are over one million persons in the United States suffering from parapneumonic effusions yearly, and 10%~20% of them develop a complicated parapneumonic effusion (CPE) or pleural empyema (PE) (Sahn, 1993). The CPE and PE remain conditions with substantial morbidity, despite effective antibiotic treatment that made their incidences decrease (Lemmer *et al*., 1987; Neild *et al*., 1985).

The appropriate management of CPE or PE remains controversial. Most of them are treated initially by antibiotics with or without repeat thoracentesis, closed thoracostomy or fibrinolytics (Mandal and Thadepalli, 1987; Colice *et al*., 2000). Surgical approaches, such as open thoracostomy, decortication, and thoracoplasty, are reserved for patients with poor outcome CPE/PE, or conditions refractory to the aforementioned conservative treatments (Colice *et al*., 2000; Bayes *et al*., 1987; Gregoire *et al*., 1987; Hoover *et al*., 1986; Luh *et al*., 2005).

VATS plays a bridging role between the medical and aggressive surgical managements, and has assumed greater importance in the treatment of CPE/PE (Landreneau *et al*., 1995; Bouros *et al*., 2002; Klena *et al*., 1998; Stammberger *et al*., 2000; Liu *et al*., 2002). The recent development of angled video-optical endoscopic equipment and more effective endosurgical instrumentation has expanded the role of VATS approaches to a wide variety of thoracic surgical problems previously requiring thoracotomy (Mack *et al*., 1992; Ridley and Braimbridge, 1991).

From 1987~2002, 44 retrospective studies with a total of 1369 pediatric patients (MEDLINE database in English and Spanish-language articles) were available. This is not a true meta-analysis because of inherent institutional bias and variability in outcome measures among studies. Kruskal-Wallis nonparametric test was used to compare methods detailed in the individual studies. Four strategies were compared: chest tube drainage alone (16 studies, 611 patients), chest tube drainage with fibrinolytic instillation (10 studies, 83 patients), thoracotomy (13 studies, 226 patients), and VATS (22 studies, 449 patients). Results: VATS associated with shorter hospital stay. The duration of chest tube placement and antibiotic use is uncorrelated with treatment methods. Limitations: Need multi-institutional, randomized, and prospective studies for the development of evidence based medicine (EBM) standards (Gates *et al*., 2004).

2. Malignant pleural effusions (MPEs)

Malignancy is the second most frequent cause of pleural effusion in patients over 50 years old. Approximately 40% of all pleural effusions are malignant and about 100000 occur each year (Marthay *et al*., 1990; Burrows *et al*., 2000). One-half of all patients with metastatic cancer developed malignant pleural effusions (MPEs) (Burrows *et al*., 2000). Lung cancer is the most common primary malignancy, followed by breast, lymphoma, ovarian, and gastrointestinal tract carcinoma; the above comprise over 80% of all carcinomas in patients with MPE (Burrows *et al*., 2000; Sahn, 1998).

The prognosis of patients with MPE is poor, with reported 1- and 6-month mortality rates of 54% and 85%, respectively (Sahn, 1998; Wang and Goldstraw, 1993). The mean survival once MPE appears is less than 6 months (Davies *et al*., 1999; Belani *et al*., 1998), ranging from 2.5 months for patients with lung carcinoma to 7 months for patients with breast carcinoma (Wissberg and Ben-Zeev, 1993). The main symptoms at diagnosis are dyspnea (96%), chest pain (57%), and cough (44%), with the volume of the effusion usually exceeding 500 ml. These symptoms limit exercise ability and impair quality of life (Martínez-Moragón *et al*., 1998).

Treatment for MPE is palliative and focuses on safe, efficacious, and cost-effective symptom relief. Treatment options include fluid drainage and pleurodesis via thoracostomy or with thoracoscopic assistance (Toms *et al*., 2000; Patz, 1998; Erasmus and Patz, 1999; Erasmus *et al*., 2000; Light, 2000). The use of video-assisted thoracic surgery (VATS) for the treatment of MPE is advantageous in that it allows optimal preparation of the pleural surface and homogeneous pleurodesis under visual control.

In pulmonary benign or malignant diseases

1. Cancer diagnosis/staging

VATS has also been established as an essential minimally invasive diagnostic tool for lung cancer staging and substaging. It has the benefits of histological and molecular staging (Sihoe and Yim, 2004). Traditionally, CT is the most sensitive method to detect the lung nodule, and spiral CT can detect subcentimeter pulmonary nodules (SCPNs) requiring further diagnostic workup. Bronchoscopic or needle biopsy of the majority of SCPNs is not practical. VATS is possible for SCPNs but should be performed in a controlled manner to reduce the resection of benign lesions (Miller, 2002). The SCPN management algorithm was also shown in this paper (Whyte, 2001). In North America they still preferred mediastinoscopy, and VATS was used only in selected cases (Whyte, 2001).

Although VATS has been shown to be highly successful in the diagnosis of lung lesions, it remains an operative procedure requiring general anesthesia and hospital stay, and thus needs inherent cost for training and equipment (Moffatt *et al*., 2002).

Increasing use of neoadjuvant treatment in the surgical management of lung cancer has rendered initial staging more important. Conventional modes of staging, including CT, bronchoscopy, and even mediastinoscopy, lack diagnostic accuracy in the evaluation of mediastinal nodal metastases. Consequently, the diagnosis of lung cancer by combined video-assisted mediastinoscopy and thoracoscopy should be considered.

2. Minor lung resection

Limited resection for the diagnosis of SCPN has been described in above (Miller, 2002). Some series reported that limited resection (wedge or segmentectomy) may yield good long-term outcome in selected cases, as does lobectomy, but still has no strong evidence for publication. VATS is less invasive and has compatible effectiveness in the treatment of Stage I non-small cell lung cancer (NSCLC) (Endo *et al*., 2003).

3. Major lung resection

There is still much debate on the role of VATS in major lung resection, especially for the treatment of lung cancer. Kaseda and Aoki (2002) reported their 10-year experience in VATS lobectomy for Stage I lung cancer, with 97.2% 8-year survival rate for Stage IA lung cancer, better than outcomes by thoracotomy. VATS lobectomy for lung cancer has the benefits of less pain, shorter hospital stay, less inflammatory response and better long term functional level (extremity movement) (Swanson and Batirel, 2002). However, the survival advantage needs further Phase III trial.

Minimal invasive surgery still has its drawbacks and limitations in the treatment of cancer. Questions on the role of VATS in the treatment of lung cancer include the training, cost containment, and oncological aspects. Limited resections are avoided when possible because of higher recurrence rates and potentially worse long-term survival (Korst and Ginsberg, 2001). VATS is usually considered in patients with Stage I NSCLC. Although characterized be less pain and faster recovery, the acceptance of VATS is variable. The absolute indications of VATS for lung cancer have yet to be defined (Russo, 2002). Tumor recurrence over the port site has never been reported, however, the risk would not be higher than patients undergoing pulmonary resection through standard thoracotomy (Parekh *et al*., 2001).

VATS lobectomy can be performed through utility minithoracotomy, as were presented in previous literature (Solaini *et al*., 2001; Nomori *et al*., 2001). Pulmonary hilar dissection can be performed sequentially (Solaini *et al*., 2001; Nomori *et al*., 2001) or stapled simultaneously (Lewis *et al*., 1999). There were less than 10% of patients who needed converting to standard thoracotomy. The operation time halved after 10-year training and the complication rate 11% less than thoracotomy (Solaini *et al*., 2001). The 5-year survival rate for the Stage IA lung cancer was over 90%.

In esophageal diseases

1. Esophagectomy

Thoracoscopic esophagectomy has been described in (Gossot *et al*., 1992). This treatment for malignancy may have some benefits, such as less pain and better preservation of pulmonary function postoperatively (McAnena *et al*., 1994; Akaishi *et al*., 1997). However, these have not been widely accepted. Although neoadjuvant therapy has been developed in recent years for the new modality of treatment for some esophageal carcinomas, complete surgical resection is still regarded as the best treatment providing the best chance for cure. Thus traditional transthoracic esophagectomy is undoubtedly the first choice because it provides good exposure that makes extended lymphadnectomy, which has been proved with longer survival by better locoregional control, easier to perform (Collard *et al*., 1993; Dexter *et al*., 1996). The problems of transthoracic esophagectomy include significant postoperative pain and pulmonary complications, which increase the morbidity and prolong hospital stay (Dexter *et al*., 1996; Nagawa *et al*., 1994; Lee and Miller, 1997). Thus transhiatal esophagectomy, which can remove the esophagus without the use of esophagectomy, has gained popularity in some series. However, it is not accepted as a curative treatment because it dissected the paraesophageal lymph nodes only. Moreover, it is a blinded procedure, and so has higher surgical complications such as bleeding or tracheo-bronchial tree injuries (DePaula *et al*., 1995; Luketich *et al*., 1998a).

In this respect, VATS approach offers an interesting alternative, with the advantages of transhiatal or transthoracic approaches (Akaishi *et al*., 1996; Cuschieri *et al*., 1992). The techniques of esophagectomy and reconstruction include laparoscopic transhiatal esophagectomy, thoracoscopic and laparoscopic esophagectomy, and laparoscopic gastric mobilization with right mini-thoracotomy (Luketich *et al*., 1998b; Law *et al*., 1997; Nguyen *et al*., 1999). According to some reported series (Dexter *et al*., 1996; Law *et al*., 1997), the survival rate for patients with esophageal carcinoma undergoing VATS esophagectomy has results similar to those for patients undergoing transthoracic esophagectomy. However, some other series reported that the pulmonary complications cannot be effectively decreased by using VATS approach (Nagawa *et al*., 1994; Robertson *et al*., 1996; Gossot *et al*., 1995). Therefore the interest in VATS esophagectomy seems to decline throughout the USA and Europe, but is still actively tried in some series in Japan and Asia (Akaishi *et al*., 1996).

2. Anti-reflux surgery

Gastroesophageal reflux disease (GERD) can result in many complications, such as esophageal inflammation, ulceration, stricture or Barrett's esophagus (a type of pre-malignancy change). The role of surgery in the management of GERD has become more important after the application of laparoscopic techniques to antireflux operations (Wu *et al*., 1996; Pitcher *et al*., 1994; Sataloff *et al*., 1997). VATS was rarely applied in the treatment of GERD.

3. Myotomy for achalasia

Achalasia of the esophagus, characterized by a long history of dysphagia, regurgitation of undigested food and weight loss, is caused by inadequate lower esophageal sphincter (LES) relaxation. Several treatments can be chosen, such as medical (calcium entry blocker or botulinum toxin) treatment, balloon dilatation, and surgery (myotomy). Myotomy can be performed by thoracoscopic or laparoscopic approach (Pelligrini *et al*., 1993; Shimi *et al*., 1991; Hunter *et al*., 1997). The latter has some advantages, such as easier in anesthesia and surgical approach. Moreover, the myotomy can be clearly extended into the stomach and antireflux procedure can be easily performed by laparoscopic approach (Shimi *et al*., 1991; Hunter *et al*., 1997). VATS myotomy is reserved for patients who have diffuse esophageal motor disorders or recurrent symptoms after laparoscopic procedures (Pelligrini *et al*., 1993).

In mediastinal lesions

1. VATS approaches to thymus

(1) For Myasthenia Gravis (MG): There exist some controversies over the optimal treatment of MG. The choices of surgical approach for thymectomy include median sternotomy with or without a transverse cervical extension, partial sternotomy, transcervical or VATS approach. Some series advocated maximal thymectomy (Jaretzki *et al.*, 1988), which remove not only the thymus but also anterior mediastinal fat in front of the phrenic nerve. However, the clinical improvement was not significantly better than the conventional trans-sternal or transcervical approach (Cooper *et al.*, 1987). The VATS approach for thymectomy result in significantly less pain and lower analgesic requirement, as well as shorter hospital stay and cosmetically better wound (Yim *et al.*, 1995). The VATS thymectomy for MG showed no significant difference in clinical improvement from the series performing trans-sternal thymectomy (Cooper *et al.*, 1987; Mack *et al.*, 1996; Kay *et al.*, 1994). There are also controversies over the techniques of VATS approach. Some series advocated left-sided approaches (Mineo *et al.*, 1996) but some other series approached through the right side (Mineo *et al.*, 1997; Yim, 1997). The goal of VATS approach for MG is to remove the thymus and the anterior mediastinal tissue completely, and which side to approach depends on the surgeon's preference.

(2) For thymoma: VATS approach for thymoma is still limited to patients with Masaoka Stage I (well encapsulate) tumors (Landreneau *et al.*, 1992a). The ultimate concern for the treatment of thymoma is the complete resection of the mass and the thymus, instead of the methods of approach.

2. VATS approaches to posterior mediastinum

Many reports documented that VATS can be used safely in the diagnosis and treatment of posterior medicastinal lesions, such as neurogenic tumors, mediastinal cysts, esophageal leiomyomata, and paravertebral abscesses (Bardini *et al.*, 1992; Bousamra *et al.*, 1996; DeCamp *et al.*, 1995). There are several important considerations before performing VATS for posterior mediastinal masses. At first, the chest CT scan has to be reviewed to exclude intraspinal involvement (the "dumbbell tumor"). All dumbbell lesions had to be evaluated by the neurogeons. Then, the possibility of lymphoma should be excluded, in which fine needle biopsy should be first considered. Last of all, the possibilities of pheochromocytoma or ganglioneuroblastoma should be excluded. These lesions rarely appeared in adults, and the release of catecholamine intraoperatively might result in severe problems. After exclusion of the above conditions, VATS can be safely performed for the resection of posterior mediastinal masses (Heltzer *et al.*, 1995; Hazelrigg *et al.*, 1993a; Liu *et al.*, 2000a).

VATS in chest trauma

VATS plays a definitive role in the diagnosis and treatment of thoracic trauma. VATS can be indicated in patients with hemodynamically stable acute or retained hemothorax, empyema, diapharagmatic injuries, chylothorax, foreign body removal and treatment of persistent air leakage from lung parenchyma (Aram *et al.*, 1997; Bartek *et al.*, 1996; Graeber and Jones, 1993; Graham *et al.*, 1994; Heniford *et al.*, 1997; Liu *et al.*, 1997b). However, it is contraindicated in patients with unstable hemodynamics, major airway injury, massive hemorrhage or inability to tolerate one lung ventilation (Jones *et al.*, 1981; Lang-Lazdunski *et al.*, 1997; Smith *et al.*, 1993).

VATS in sympathectomy or splanchnicectomy

VATS upper thoracic sympathectomy is applied most commonly in patients with palmar (T2 and T3) or axillary (T4) hyperhidrosis, followed by Raynaud's syndrome or Buerger's disease of the upper limb (Byrne *et al.*, 1993; Drott and Claes, 1996; Lau and Cheng, 1997). VATS lower thoracic sympathectomy or splanchnicectomy, which should be first and mainly performed on the left side, is indicated in patients with intractable upper abdominal pain from malignancy or pancreatitis (Noppen *et al.*, 1998). VATS upper sympathectomy should be reserved for patients with severe hyperhidrosis and refractory to other treatments, because the incidence of compensatory sweating, a troublesome complication, is extraordinarily high (Andrews and Rennie, 1997; Herbst *et al.*, 1994).

VATS, FUTURE PERSPECTIVES

VATS, although widely applied, still has some difficulties for surgeons because of the loss of 3D vision, sense of touch and dexterity. A number of systems, such as telepresence operation systems have been developed to solve these problems by increasing the dexterity, adding motion tracking and filtering tremor motions (Satava, 1995; Hill *et al*., 1998; Garcia-Rutz *et al*., 1997). It can also be applied in the field of surgical education that students can perform VATS surgery by using virtual reality surgical simulators, instead of the real patients (Playter and Raibert, 1997; Delp *et al*., 1997). The challenge of applying these techniques in the human body is far more difficult than their uses in other industries. Nonetheless, we believe that these obstacles will be surmounted in the near future.

VATS, COST ANALYSIS

Regarding the cost analysis of VATS versus thoracotomy, many factors should be considered, such as selection criteria for VATS, general hospital charges, operative cost of equipment and disposables, operative time and room charges, postoperative morbidity or mortality, duration of chest tube drainage and length of stay, outpatient management, long-term benefits or complications (van Schil, 2003). The cost of equipment and disposables is higher for VATS. However, VATS may result in more rapid recovery and shorter hospital stay (Liu *et al*., 2000b). So far there is still lack of prospective randomized study to compare the cost differences between VATS and thoracotomy in certain procedure. Some retrospective or non-randomized studies revealed different results in various thoracic surgical procedures, such as lung biopsy, wedge resection of lung, pneumothorax, lung volume reduction surgery or lung cancer (Molin *et al*., 1994; Hazelrigg *et al*., 1993b; Sugi *et al*., 1998; Crisci and Coloni, 1996; Kim *et al*., 1996; Ko and Waters, 1998). In conclusion, procedure related costs of VATS are higher but the benefits have not been clearly demonstrated.

CONCLUSION

The development of thoracoscopy has almost one-hundred years of history. It was not widely applied in surgery until the video-assisted devices were incorporated in the last two decades. At present, most basic and many advanced thoracic surgical procedures can be performed by VATS, with smaller wounds, less pain, shorter hospital stay, and with as good outcomes compared with conventional surgery. It is believed that there will be more and more surgical procedures being performed by VATS. However, surgeons should keep in mind that VATS is only a method, instead of the goal, of the treatment. And thus conversion to open procedures should be done without hesitation if patients' life safeties were threatened or oncological principles were compromised.

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